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NAVSEC SHIPBOARD HABITABILITY DESIGN PROCESS, (U)
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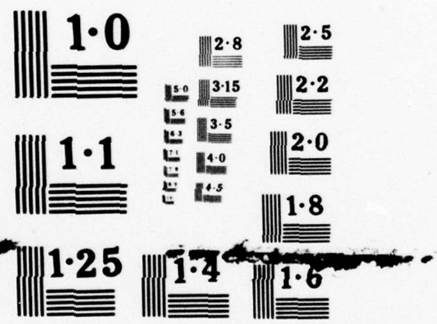
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ASSOCIATION OF SCIENTISTS AND ENGINEERS

THE SHIPBOARD HABITABILITY DESIGN PROCESS

Joseph E. Castle

14TH ANNUAL TECHNICAL SYMPOSIUM

ASSOCIATION OF SCIENTISTS AND ENGINEERS OF THE NAVAL AIR AND SEA SYSTEMS COMMAND
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NAVSEC SHIPBOARD HABITABILITY
DESIGN PROCESS

by

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ABOUT THE AUTHOR

JOSEPH CASTLE was graduated from George Washington University in 1968 with a B.S. in Civil Engineering. He started as a Civil Engineer in the Naval Ship Engineering Center, Hull Design Division. After a year's training, including five weeks aboard U.S. Navy Ships in Guantanamo Bay, Cuba, he was classified as a Naval Architect and assigned to the Habitability Section, Ships Arrangements Branch. He spent a year at the University of California at Berkeley in Navy sponsored research in human factors and environmental design and received his M.S. in Industrial Engineering. He is a member of ASE, ASNE, SNAME, and the Human Factors Society. He has co-authored: "The Naval Architect's Role in Achieving Shipboard Livability" (ASE March 1971); "The Shipboard Environment - Past, Present, and Future" (ASNE April 1971); "The Need for an Open Systems Approach to Shipboard Habitability Design" (SNAME November 1972); and "Female Personnel Aboard Ships - Habitability Design Considerations" (ASE March 1973).

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ABSTRACT

This paper discusses how U.S. Navy shipboard habitability design requirements are generated and satisfied, documents the deficiencies associated with this process, and proposes more effective methods for identifying and satisfying these requirements.

TABLE OF CONTENTS

I. CURRENT PROCESS AND ITS EVOLUTION

A. 1951 TO 1968

Prior to 1951, little formalized engineering consideration was given to the design of living and working conditions aboard naval ships (reference (1)). In 1951, the Commander in Chief, U.S. Atlantic Fleet (CINCLANTFLT) concluded that the addition of equipment and personnel to ships which were not designed to accommodate them was adversely affecting their military effectiveness. CINCLANTFLT tasked Commander, Atlantic Fleet Operational Development Force (COMOPDEVFOR) to: conduct a Fleet survey of the facilities affecting health, comfort, sanitation and morale, review standards for berthing, messing sanitation and other factors affecting habitability, and establish minimum habitability standards for incorporation in specifications and Navy Regulations.

The task resulted in a three year investigation consisting of: design work studies; a survey issued to 177 surface ships and 24 submarines to determine the extent to which existing habitability standards were satisfied; data collection on noise, temperature, ventilation, and lighting aboard ten ships during at sea operations; and an opinion survey to determine the relative importance of various habitability items, involving a questionnaire completed by 5575 enlisted men and 1801 officers on 138 surface ships.

COMOPDEVFOR found no complete compilation of habitability standards. Habitability standards were dispersed throughout several publications including Bureau of Ships Manual, Bureau of Ships Allowance List, General Specifications for Ships of the U.S. Navy, Manual of Naval Hygiene, and the Bureau of Medicine Manual. There were no official requirements for standards to be met, and standards were being compromised without penalty. COMOPDEVFOR compiled existing standards, compared them with human engineering data and the findings from its investigation, and developed new standards. These standards covered: berthing, lounge, recreation, sanitary, food service, barber shop, post office, ship store, library, chapel, physical fitness, brig, and laundry facilities and established minimum requirements in terms of heating, ventilation, air conditioning, noise, lighting, fresh water, clearances, net walking area, color, sanitary fixtures, stowage, mess seating, serving time, and arrangements within and between compartments.

In 1953, COMOPDEVFOR submitted the proposed standards to the Office of the Chief of Naval Operations (OPNAV). The standards were reviewed, and then issued in 1957 as Environmental Control Standards under OPNAVINST 9330.5 which states that: (a) habitability is a military

characteristic of ships of equal importance with other military features, (b) the standards are the minimum acceptable in new construction ships, and (c) that departures from the standards must be referred to the Chief of Naval Operations for approval. The standards were updated in 1960, 1965, and 1968. The current (1968) standards are contained in reference (2).

With the issuance of the standards, the habitability design process became as follows:

1. OPNAV invoked the habitability standards.

2. Based upon accommodations, endurance, the habitability standards and previous designs, area, volume, power, and weight estimates for habitability were derived and utilized in feasibility and concept design studies. During these phases of design, the single habitability concern was that enough space was reserved to satisfy the standards. Concept design resulted in spaces reserved for habitability functions.

3. The major habitability design effort occurred in preliminary and contract design, where designers worked with spaces designated for berthing, recreation, sanitary, galley, messing, scullery, laundry, barber shops, ship store, medical/dental, offices, library, chapel, physical fitness and brig. Habitability designers selected and manipulated furniture and equipment within the designated spaces to meet the corresponding requirements in the OPNAV Standards and General Specifications, and then developed detailed arrangements and ship specifications.

4. During ship construction and after delivery, the OPNAV Standards were frequently violated, sometimes with, but more often without, OPNAV approval. Nevertheless, ships built to the habitability standards were a marked improvement.

In 1959, support for habitability began to decline and, as a consequence, shipboard conditions began to deteriorate. This continued until, in 1965, "The Report of the Secretary of the Navy's Task Force on Retention of Navy and Marine Corps Personnel" cited poor habitability as being a major factor contributing to the problem of retention of shipboard personnel. As a result of the Task Force report, the Secretary of the Navy issued a notice, SECNAVNOTICE 5420 of 14 February 1966, which directed offices, commands, and activities of the Department of the Navy to exert a continued effort to: develop adequate growth factors for ships; resume funding of the Habitability Improvement Program and direct an annual review of environmental control standards.

B. 1968 TO 1975

In 1968, NAVSEC initiated its current Habitability Improvement Program. The program concentrated on upgrading existing ships, and applied the results to new designs on an "as can" basis. Basically, the approach was as follows: visit ships and gather Fleet input; develop design solutions to improve habitability spaces; evaluate improvements on a trial basis; obtain OPNAV approval and money for implementing improvements on a Fleet-wide basis; and integrate improvements into current designs and the Habitability Standards.

1. Ship Visits and Fleet Input. To better understand shipboard habitability problems, habitability designers went aboard ships, inspected facilities, and talked to personnel.

2. Pilot Test Projects. In response to their findings, NAVSEC's habitability designers developed solutions and tested them on several ships. These efforts were supported by several NAVSEC codes, including Hull Equipment, Heating, Ventilation, Air Conditioning, and Lighting. As an example, the DDG 9 (USS TOWERS) project illustrated that living conditions could be improved even under critical spatial and structural constraints (see reference (3)).

3. <u>New Designs</u>. In 1969, the CGN 38 was in preliminary design. Standard habitability was being provided. During a program review, the results of the pilot projects were discussed. As a result, OPNAV directed that a design more responsive to Fleet needs be provided in the CGN 38. It should be noted that being in preliminary design, habitability designers were forced to work within existing space allocations. The following are examples of how habitability designers incorporated their shipboard findings and Fleet input into the design.

<u>Example i</u>. Since many ship personnel reported that it was difficult to sleep surrounded by men shouting, banging lockers, and playing cards, CGN 38 berthing areas were designed exclusively for sleeping, with locker, recreation and lounge facilities in separate adjoining spaces.

<u>Example ii</u>. Since many men complained of the distance they had to travel to take a shower and use the head, sanitary spaces were located near berthing spaces. Since many men complained of sanitary spaces being hot, humid, smelly, and difficult to clean, the following was accomplished: showers and drying areas were segregated from the remainder of the sanitary space and well ventilated to prevent the entire sanitary space from becoming hot and humid; improved deck covering and coving were used to reduce required maintenance and allow easier cleaning. The traditional open sinks and piping were replaced with a counter-lavoratory unit to allow for easier cleaning.

Example iii. Since many men reported that they had no place to study except in noisy mess areas or in their cramped berths, the CGN 38 design provided quiet areas for studying and privacy, in addition to recreation areas for games and conversation. The CGN 38 design is fully discussed and illustrated in reference (4).

4. OPNAV Habitability Steering Group. NAVSEC continued to gather Fleet input and develop design methods for correcting habitability deficiencies. In 1972, an OPNAV Habitability Steering Group was established to provide a forum for centralized review, discussions, and recommendations concerning all aspects of shipboard habitability. It was composed of representatives from OPNAV, CINCLANTFLT, CINCPACFLT, the various Type Commanders, NAVMAT, NAVSEA, NAVSUP, NAVPERS, BUMED, NAVSEC, and NAVFSSO. NAVSEC presented its findings to the Steering Group and was directed to translate them into Proposed Military Improvements (PMI's). The following are examples of PMI's submitted to OPNAV: provide improved lighting and ventilation; provide bulkhead and overhead sheathing in food preparation, messing, sanitary, medical and dental spaces to improve sanitation, reduce noise, and reduce facilities maintenance (housekeeping) requirements; provide carpeting in berthing, lounges, and library to reduce noise and facilities maintenance requirements; provide countertop lavatories in sanitary spaces to reduce facilities maintenance requirements and improve sanitation; provide hanging space for new crew uniform and civilian clothes; provide privacy partitions in berthing and sanitary spaces; provide berth curtains and 6-man berthing cubicles to increase privacy; provide equivalent berthing for troops onboard for extended periods; provide sanitary facilities for continuously-manned spaces to eliminate the need for watchstanders to leave spaces.

The PMI's were presented to and approved by the OPNAV Habitability Steering Group. NAVSEC utilized the PMI's to develop ShipAlts for existing ships. For new designs, the PMI's were referenced along with the habitability standards in OPNAV's design requirements.

During this period, habitability design was also improved by the development of improved furniture, provision of closed circuit television, application of better noise, vibration, lighting, heating, ventilation and air conditioning criteria. A considerable effort was expended on the development of habitability materials (e.g., deck covering, privacy curtains, furniture) which met Navy fire safety criteria. In addition, a Habitability Manual (reference (5)), which consolidated OPNAV Standards and General Specifications, was developed and issued to provide habitability design guidance.

C. CV CONCEPT DESIGN

The major emphasis of NAVSEC's Habitability Program had been on upgrading existing ships. In 1975, NAVSEC's Habitability Section began to take a more active role in new designs. After reviewing the existing design process, it was concluded that the practice of initiating requirements in terms of spaces, furniture, equipment, and environmental control, instead of operational objectives, prevented the development of design solutions which required less resources and better satisfied specific ship requirements. It was also realized that the standards concentrated on physical needs and did not address social and psychological needs. As a result, a new approach was developed and applied to the CV concept design.

The CV approach attempted to break away from the traditional "cookbook" approach of responding to standards and general specifications, and attempted to provide habitability more responsive to specific ship needs. For the first time a behavioral scientist, a sociologist, participated in the design to address social and psychological needs. Basically, the approach consisted of the following stages:

1. Define the problems to be addressed utilizing data accumulated from shipboard visits and findings of behavioral science research.

2. Identify requirements and constraints.

3. Develop baseline solution, utilizing habitability standards and PMI's.

4. Examine baseline solution in terms of requirements and constraints.

5. Develop design alternatives which better satisfy requirements and constraints.

6. Evaluate alternatives.

7. Select design.

The approach is more fully discussed in reference (6). In actuality the approach was only carried out to a limited degree because of funding, schedule, and contractual constraints.

Stage 1 identified five broad design characteristics which an aircraft carrier habitability system must address:

- Human physiological needs
- Individual privacy
- Group cohesiveness
- Space identification
- Opportunity for diversification

This effort also identified specific difficulties on existing CV's including:

- High density population/prone to tensions
- Lack of cohesion or comradeship found on small ships
- Long waits in mess lines
- Poor designs which hinder maintenance efforts
- Sailors with much "dead time".

Unfortunately, there was not enough time for the behavioral scientist to work with designers and help formulate solutions to these problems. It became evident that a significant amount of data must be gathered, analyzed, and transformed into design criteria before a specific project begins.

In Stage 2, a study was conducted to establish a range of deck areas within which a CV habitability space budget could be assigned. The upper and lower limits of this range were fixed by proportioning the functional space allocations of the Sea Control Ship (habitability based on OPNAV Standards and PMI's) and the CVAN 68 (existing habitability conditions which do not meet OPNAV Standards) to the complement of the CV (see Table 1).

CV HABITABILITY DECK AREAS

	SCS	CVAN 68	CV		
Type of Space	ft^2/man	ft^2/man	# of Personnel	Gross Area Based on SCS (ft^2)	Gross Area Based on CVAN 68 (ft^2)
Officer Living	93.78	87.77	337	31,604	29,575
CPO Living	51.78	36.33	192	9,942	6,975
Enlisted Living	29.73	24.00	3,002	89,250	72,048
Etc.	Etc.	Etc.	Etc.	Etc.	Etc.
				Total = 163,889	Total = 144,915

TABLE 1

The total available resources (e.g., 145,000 to 164,000 sq. ft.) were to be utilized in satisfying specific CV design requirements and solving the problems identified in Stage 1. To do this, requirements were to be expressed as basic needs and operational objectives. Unfortunately, cognizant activities stated subsystem requirements in terms of space, furniture, and equipment and optimized their systems without regard for the total habitability system. For example, instead of stating that each man must get a hair cut every X-days in order that his hair length complies with specific Navy Regulations, it was stated that there was a requirement for a crew, a CPO, and an officer barber shop, and that so many square feet and a certain number of barber chairs were required for each. By stating requirements in this fashion, the only alternatives investigated were where to place the barber shops within the ship.

Therefore, instead of resources being allocated according to need, resources were distributed according to past design practices. Instead of addressing habitability as a total system, the CV effort concentrated on subsystem design. Even in the design of subsystems, the tendency was to rely on past design practices. Consequently, after NAVSEC satisfied requirements for food service, ship store, vending machines, barber shops, ice cream bars, laundry, dry cleaning plant, and tailor shop, the only areas left for trade-offs were berthing, sanitary, lounge, and recreation spaces and even here, there were in fact few degrees of freedom exercised.

But even with the above problems, the CV approach itself was inherently superior to the old process. The CV Project did produce solutions to design problems which, while not optimal, were better than what had been done in the past. The approach proposed in the next section is directed at correcting the problems which occurred in the CV concept design and obtaining design solutions which better satisfy specific ship requirements.

II. PROPOSED DESIGN PROCESS

In ship design, limited resources should be allocated to maximize the probability that the ship will satisfy mission requirements. Each subsystem can cause an overall system failure. For example, poor habitability can produce outbreaks of dysentery and prevent ships from performing their missions. Therefore, the risk associated with each subsystem should be reduced to a level which minimizes the overall risk. It must be realized that if a subsystem such as habitability receives all the resources it needs to reduce its risk contribution to zero, that the risk levels associated with other subsystems will in all likelihood increase, resulting in a net total risk increase.

A. MUSTS VERSUS WANTS

In buying a house, the purchaser should determine his "must" requirements, e.g., the house must cost less than $50,000; the house must have at least three bedrooms; the home must be within an hour's drive of work. These "musts" are the criteria the house absolutely has to satisfy or he will not buy it. Next, the purchaser considers his "wants", e.g., *he would like to have four or more bedrooms*; he would like to be within a 30 minute drive to work. The buyer may not find a house which satisfies all his musts and wants. Therefore, he should prioritize his wants, establish evaluation criteria, evaluate those houses which satisfy his musts, and make a selection.

In ship design, there are not enough resources (space, dollars, etc.) to satisfy all habitability musts and wants (see Figure 1). Therefore, habitability designers need to:

- Determine which personnel activities* must/should take place within habitability spaces. (Basic musts/wants).
- Determine what must/should be provided to allow the activities to take place. (Supportive musts/wants).
- Identify the resources required to satisfy the musts and wants
- Compete with other ship subsystems to obtain a fair share of resources.
- Insure that available resources are utilized to satisfy the musts and the more important wants.

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* NOTE: In the proposed process, the basic unit of musts and wants is an "activity" (e.g., sleep). The next level of musts and wants are attributes associated with the performance of the activity (e.g., horizontal surface to sleep).

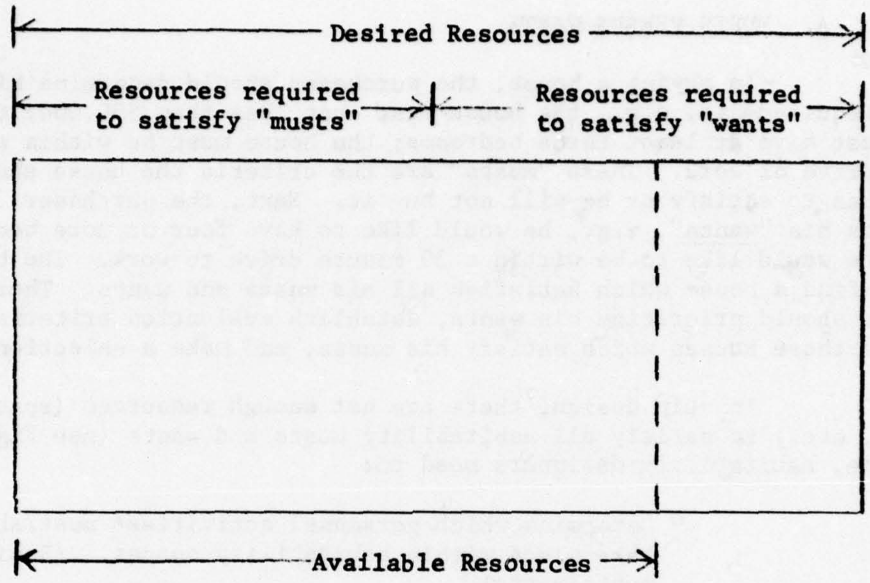

FIGURE 1. Desired Versus Available Resources

In broad terms, then, the musts are those activities which have to take place within habitability spaces so that personnel <u>can</u> perform their work-related tasks. The wants are those activities which should take place to increase the probability that personnel <u>will</u> perform their tasks effectively.

B. WORKING GROUP

Being limited to what it alone can do, NAVSEC must work with other Navy activities to improve shipboard habitability design. The Work Research Institute of Norway has made considerable progress in satisfying ship owners' and operators' needs by conducting habitability design workshops attended by ship owners, operators, and designers. It is proposed that a similar working group be established to support NAVSEC's design efforts. The group should be composed of one representative from OPNAV, BUPERS, NAVSEC, NAVSUP, and the Fleet and a behavioral science consultant. Although the OPNAV Habitability Steering Group was influencial in achieving habitability improvements, it was not an effective body for determining what improvements should be accomplished. It was not a balanced group in that the Fleet was exclusively represented by officers, and designers had very little voice. The proposed working group must be able to state what the Fleet needs and wants, what OPNAV can afford, and what NAVSEC can provide. The responsibilities of each representative would be as follows:

Representative	Responsibilities
OPNAV	State habitability requirements, constraints, and shipboard policies. Work with other OPNAV codes to modify policies as necessary.
Fleet	State existing habitability deficiencies. Provide input regarding musts and wants.
BUPERS	Describe personnel who will be operating ships. Provide information regarding manning, training, uniforms, clothing, and religious and detention facilities. Obtain Fleet representatives to provide user-input and evaluate design alternatives. Provide habitability related findings from personnel research labs.
NAVSUP	State supply facility requirements and suggested design alternatives for laundry, dry cleaning, food service, ship store, barber shop.

Behavioral Science	Provide information regarding personnel needs, human behavior, and man-environment relationships.
NAVSEC	State design constraints. Develop/present/discuss alternatives. Integrate working group input into ship design.

When necessary, working group representatives can bring in experts from their activities to discuss specific problems. To promote communications between the designer, the Fleet, and other participants, arrangement drawings, renderings, models, mock-ups and other methods should be utilized. These tools help the designer convey the fact of limited resources and allow the "user" and "owner" to participate in developing alternatives. The working group approach allows policy maker and design representatives to clarify operational objectives and discuss organizational policies in terms of their impact on space utilization within ships.

C. PROPOSED PROCESS

1. Feasibility Design. If there are no unique ship requirements and habitability resources are equivalent to those provided in previous designs, the design in all likelihood will be feasible from a habitability standpoint. If there are unique ship requirements, e.g., extended mission or reduced habitability space, then the design may not be feasible from a habitability standpoint. In either case, the following steps should be taken in preparation of Concept Design.

a. As it does now, OPNAV describes the ship's mission, operational requirements, major configuration constraints, the plan for use, maintenance concepts, supply support concepts, manning limitations, minimum operational standards, maximum allowable cost, etc.

Manning is a key factor in that it serves as a basis for estimating habitability volume, area, weight, and power requirements. A major habitability design problem is that as the design progresses (and after the ship is delivered to the Fleet), manning increases while resources decrease or remain the same. In reference to Figure 1, the resources available to satisfy "wants" decreases. To complicate matters, the time available for obtaining a design solution decreases as the design problem becomes more complex. Much of the analysis and thought given to the early phases of design are of little value when manning changes significantly. *With increased manning and reduced resources per* man, previously derived concepts, solutions and recommendations are no longer applicable. In many ways, it would be better to have accurate manning estimates and less resources per man, in that this allows more time to develop a good solution in terms of space utilization and a balanced design. Accordingly, there is a need to establish more accurate manning estimates or growth margins for habitability purposes.

b. NAVSEC analyzes relevant ship requirements (e.g., mission, manning, endurance, operating conditions) and information from BUPERS to determine what the ship will be doing and the characteristics of the people who will be operating it.

c. NAVSEC, with the assistance of the working group, develops a scenario describing personnel activities which must or should take place. In addition, support activities have to be identified. For example, if it is decided personnel have to eat, several activities may be necessary to allow this activity to take place (e.g., store, prepare and serve food, and dispose of waste). It is important that "musts" be limited to absolute requirements. Otherwise, good alternatives may be eliminated. NAVSEC's design work study and manning people should participate in the development of the scenario, describing what activities are to take place in the work environment. This will

help habitability designers better determine what activities need to take place in habitability spaces. For example, different work tasks may require different activities to take place in habitability spaces. An individual who performs heavy manual labor may need to participate in different activities in habitability spaces than an individual who performs tedious mental tasks. As another example, for certain individuals some habitability-related activities (e.g., study) may take place in their work spaces (e.g., shipboard office after working hours) and need not take place in their habitability spaces.

As shown in Figure 2, the scenario begins with ship personnel coming aboard with their clothing and personal effects and proceeds to describe the activities performed by individuals representative of the total ship population. Each activity should be challenged before it becomes a must or want. (NOTE: In Figure 2, musts and wants are identified by "M" and "W" respectively.) Although an activity normally takes place aboard ship (e.g., stowing the dress uniform), it may be decided that for the new design, this activity is not necessary (e.g., the uniform will not be worn at sea and will be stowed ashore). Also, there may be other means for satisfying the purpose of certain activities. For example, movie viewing is an activity which normally takes place for recreational purposes. There may be less costly and more effective means for satisfying recreational needs. What personnel bring aboard ship in the way of clothing and personal effects should also be questioned in regard to ship requirements and their impact on space.

As illustrated below, the scenario results in a list of musts and wants:

Musts	Wants
sleep	study
eat	obtain privacy
urinate	read
defecate	write
shower	watch movie
brush teeth	

Most of the musts will be common to all personnel, however, the wants may vary. Therefore, the resources available for wants may be utilized differently for different individuals. For

HABITABILITY SCENARIO

SHORE	SHIP: WORK SPACES	SHIP: HABITABILITY SPACES	TIME
(1) Comes Aboard	(2) Goes to Hab Space	(3) Stows clothing and personal effects (M)	0700
Clothing Personnel Effects	(4) Reports to Work		0800
			0900
	(5) Goes to Hab Space	(6) Urinates (M)	1000
	(8) Returns to Work	(7) Washes hands (M)	
			1100
	(9) Goes to Hab Space	(10) Washes hands (M)	
		(11) Eats (M)	1200
		(12) Urinates/Defecates (M)	
		(13) Washes hands (M)	
	(15) Returns to Work	(14) Brushes Teeth	1300
			1400
			1500
	(16) Goes to Hab Space	(17) Urinates (M)	
	(19) Returns to Work	(18) Washes hands (M)	1600

(continued next page)

(20) Goes to Hab Space →	(21) Undresses (M)	1700
	(22) Stows Dirty Clothes (M)	
	(23) Obtains Towel (M)	
	(24) Showers (M)	
	(25) Shaves (M)	
	(26) Stows Towel (M)	
	(27) Obtains Clean Clothes (M)	
	(28) Dresses (M)	
	(29) Eats (M)	1800
	(30) Plays Cards (W)	1900
	(31) Watches Movie (W)	2000
	(32) Urinates (M)	2200
	(33) Washes (M)	
	(34) Brushes Teeth (M)	
	(35) Undresses (M)	
	(36) Stows Clothing (M)	
	(37) Sleeps (M)	2300
	(38) Awakes (M)	0600
	ETC.	

FIGURE 2

example, card playing may be considered the most important want by one group, while studying may be the most important by another. Therefore, card tables may be provided for one group versus a study area for another. Note the above list is only for purposes of discussion and not meant to be all inclusive. For example, it does not include the support activities associated with eating. A respresentative group of ship personnel should verify the musts and help prioritize the wants.

d. From existing data, NAVSEC estimates the resources required to satisfy the musts and wants. If there are not enough resources to satisfy all musts, then the design is not feasible from a habitability standpoint. Normally there will be enough resources to satisfy the musts, but not enough to satisfy all wants. Therefore, wants need to be prioritized, and available resources utilized to satisfy the musts and the more important wants. The major concern is that there are enough resources to obtain a habitability solution which reduces to an acceptable level the probability that the habitability system will cause the total ship system to fail.

e. Prepare Feasibility Design Report including the scenario, the musts and wants, support rationale, and resource estimates.

f. OPNAV reviews the Feasibility Design Report and establishes habitability requirements for Concept Design. NAVSEC and OPNAV should meet to discuss the report and ensure that habitability requirements are clearly stated and adequate resources are provided for concept design. The output of this effort identifies the activities which are to take place in habitability spaces and the resources available to support the activities taking place.

2. <u>Concept Design</u>

a. Determine whether the relationships between the activities identified in 1f are supportive (should take place in same compartment), neutral, or conflicting (should never take place in the same compartment or should not take place concurrently in the same compartment). Table 2 illustrates this process, utilizing the activities identified in Figure 2. As examples, noise from recreation activities may be in conflict with quiet conditions required for sleeping. A place to sleep and a place to gain privacy are supportive. Certain shipboard personnel policies define relationships between activities, such as separate sleeping facilities for officers, CPO's, and crew.

b. Group activities which should take place in same compartment into "sets". See Figure 3. Develop alternatives for sorting the remaining activities into existing or separate sets. See

Relationships Between Activities

	Stows clean clothing and personal effects	Urinates	Washes Hands	Eats	Defecates	Brushes Teeth	Undresses	Stows dirty clothing	Obtains Towel	Showers	Shaves	Stows Wet towel	Obtains clean clothing	Dresses	Plays Cards	Watches Movie	Sleeps
Stows clean clothing and personal effects																	
Urinates	C																
Washes Hands		S															
Eats		C															
Defecates	C	S	S	C													
Brushes Teeth				C													
Undresses	S			C													
Stows dirty clothing	S			C			S										
Obtains Towel	S							S									
Showers				C			S										
Shaves				C													
Stows wet towel	S								S								
Obtains clean clothes	S				C		S	S	S		S						
Dresses	S			C			S	S				S	S				
Plays cards		C			C		C	C		C							
Watches movie	C*	C	C*		C	C*	C*	C*	C*	C*	C*	C*	C*	C*	C*		
Sleeps		C			C		S			C					C	C	

S = Supportive (should take place in same compartment)
C = Conflicting (should not take place in same compartment)
C* = Conflicting (should not take place in same compartment at the same time. For example, if watching movie requires low illumination level, this prevents certain other activities from taking place.)
Blank space indicates neutral relationship.

TABLE 2

Stows clean clothing
and personal effects

Undresses

Stows dirty clothing

Obtains towel

Stows wet towel

Obtains clean clothing

Dresses

Urinates

Washes hands

Defecates

Eats

FIGURE 3. Activities Which Should Take Place in Same Compartment

Figure 4. Note that it may be necessary or advantageous to have an activity in more than one set.

For each alternative, determine if one or more sets may be combined to reduce area/volume requirements without adversely affecting the performance of activities. For example, it may be advantageous to combine sets #2 and #4 and sets #3 and #5 in Figure 4.

At this point, for each alternative, activities have been sorted into types of compartments. The next step is to develop alternatives in terms of the number and type of personnel to be assigned to a compartment. For each type of compartment, this determines the number required. Estimate area/volume for each compartment.

Analyze traffic patterns and adjacency requirements (Figure 5). For example, from an analysis of traffic patterns, it may be concluded that compartments #1 and #2/#4 should be in close proximity, and that an additional compartment for urinating and washing hands should be in close proximity to work compartments.

The above analysis results in design concepts, including types of spaces, their sizes, locations, and number of individuals served.

c. The next step is to evaluate the concepts. To be under consideration, each alternative has to ensure that all must activities can be satisfied within available resources and satisfy design constraints. The surviving alternatives are evaluated against the wants. All wants should compete for available resources. As previously discussed, there are not enough resources to satisfy all wants. Therefore, evaluation criteria should be established which ensure that limited resources are utilized to satisfy the most important wants. The wants associated with all habitability spaces should be compared and given weights of importance. For example, if wants such as privacy in sleeping areas are considered of utmost importance, they should be given the maximum weight.

There may be other wants such as reducing area requirements, in addition to those associated with activities. These wants must also be given weights and considered in the evaluation of the concepts. The actual evaluation procedure is very similar to that in the upcoming discussion of preliminary design. The habitability working group should conduct the initial evaluations. The concepts that survive this initial evaluation should be presented to a group of individuals representative of the Fleet for final evaluation. As previously discussed, drawings, renderings, models, mock-ups, etc., should be utilized to develop, present and discuss alternatives.

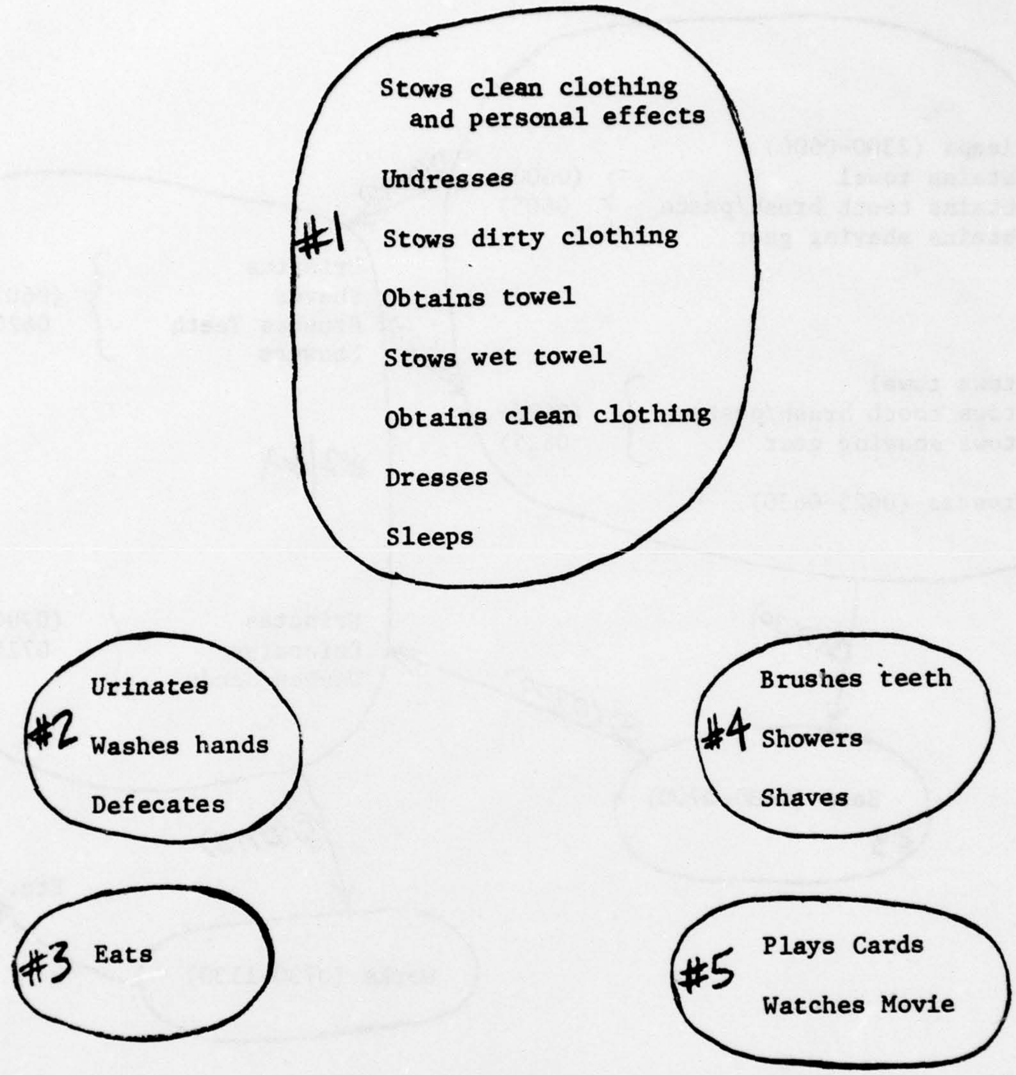

FIGURE 4. Alternative for Sorting Activities

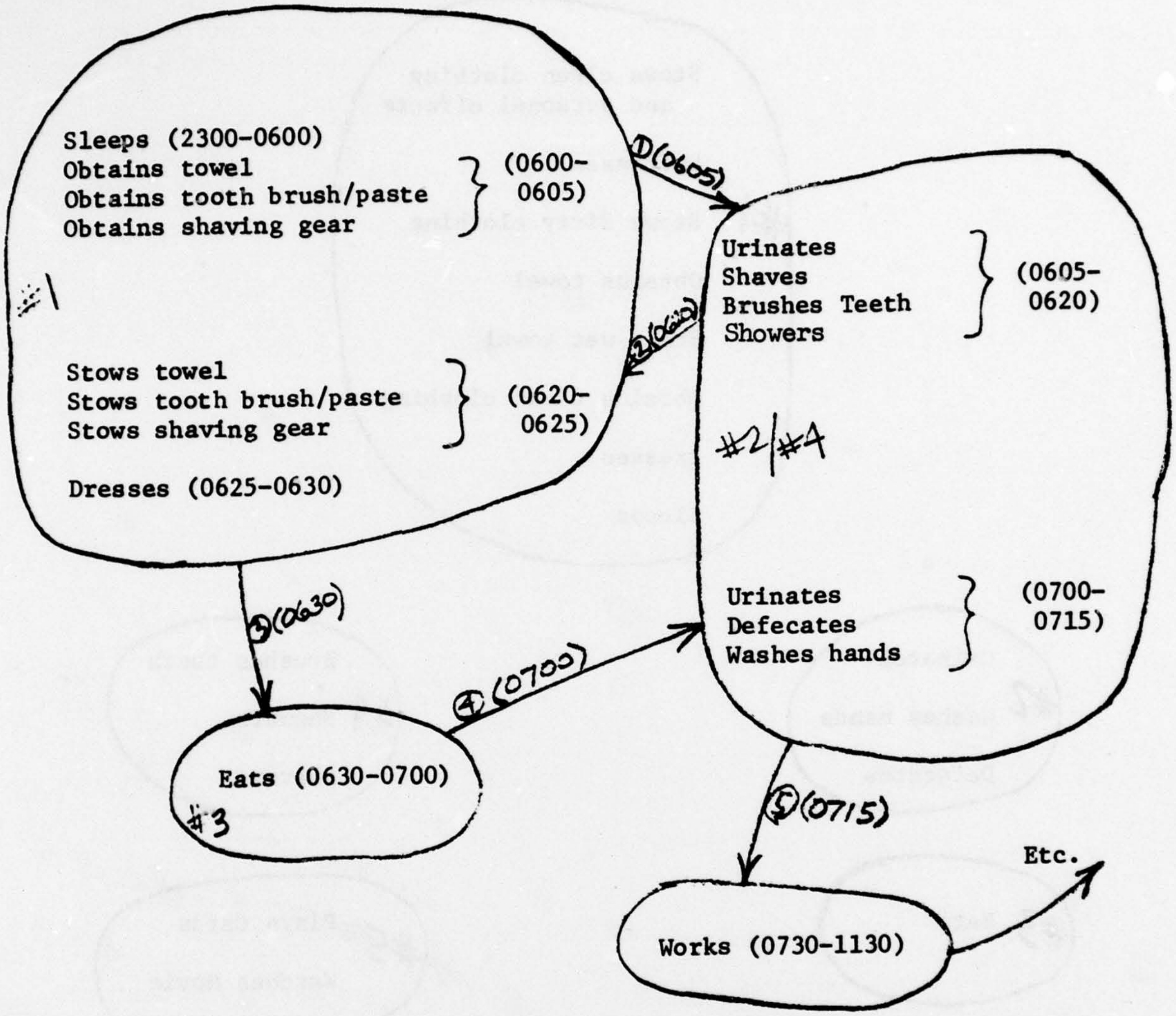

FIGURE 5. Traffic Patterns

d. After the concepts are evaluated, a Habitability Concept Design Report is prepared covering the recommended solution, the more competitive concepts, and the corresponding analysis and evaluation.

OPNAV selects the concept to be utilized in preliminary design. NAVSEC and OPNAV should meet to discuss the design concepts to ensure the best candidate is selected for preliminary design.

3. <u>Preliminary Design</u>

Concept design resulted in types of spaces plus their sizes, locations, and number of individuals served. For each space complete the following steps:

a. Identify basic and supportive musts and wants. The following exemplify basic musts associated with a crew berthing space:

- Enter/exit space under normal/emergency conditions (e.g., individual must be able to get from berth to battle station in X-seconds).
- Sleep 8 hours per day.
- Stow clothing and personal effects as identified by *BUPERS Uniform Board* (e.g., X-*shirts*, Y-pants, etc.).
- Dress/Undress.
- Maintain space (e.g., satisfy housekeeping requirements within X-hours per man per week).

The following exemplify basic wants associated with crew berthing spaces:

- Obtain privacy
- Read
- Write

The following exemplifies supportive musts associated with the basic must "sleeps 8 hours per day":

- Horizontal surface to accommodate personnel based on Navy anthropometric data.

- Vertical clearance for ingress/egress and body rotation based on anthropometric data.

- Temperature/Humidity/Ventilation control (maximum/minimum limits)

- Noise/Vibration limits.

The above generates requirements and design criteria in terms of furniture, equipment, arrangements, clearances, access, environmental control and documents the rationale behind them.

b. State constraints. Table 3 provides examples of design constraints.

EXAMPLES OF DESIGN CONSTRAINTS

Constraint	Example
Space	Available area, volume, deck height.
Furniture/Equipment	Availability. Costs. Fire Safety Criteria.
Structural	Limitation on penetration of structural bulkheads.
Damage Control	No penetrations for personnel access of main hull subdivisional bulkheads permitted below the damage control deck.
Fire Zone	Limitations on penetration of fire zone bulkheads.

TABLE 3

c. Establish Evaluation Criteria. Each alternative has to satisfy all musts and design constraints. Develop weighing values for wants, which measure their relative importance. Supportive wants are weighed in terms of their relative contributions to basic wants. Table 4 illustrates evaluation criteria for crew berthing spaces.

d. Develop design alternatives.

e. Evaluate alternatives. Those alternatives not satisfying all musts are discarded. The remaining alternatives are evaluated in terms of wants. (See Table 4).

f. Select alternative.

g. Prepare Preliminary Design Report covering the recommended solution, the more competitive designs and the corresponding analysis and evaluation.

Evaluation of Alternatives

		Alternatives		
BASIC WANT (Wt)	SUPPORTIVE WANTS (Wt)	#1 Score X Wt	#2 Score X Wt	#N
Obtain Privacy (10)	Visual Isolation (5) Sound Isolation (5)			
Read (8)	Provide min. of 42 foot candles (3) Sit (3) Minimize Noise (1) Convenient book/ magazine stowage (1)			
Write (8)	Provide min. of 42 foot candles (2.5) Sit (2.5) Writing surface (12" x 18") (2) Convenient stationery stowage (1)			

TABLE 4

h. NAVSEC and OPNAV should meet to discuss the alternatives and ensure that the best candidate is selected for contract design.

4. Contract Design

Finalize equipment selection, arrangement drawings, and ship specifications. The goal is to ensure the design is well-defined and specific enough to achieve design objectives.

III. SUMMARY

Prior to 1951, little formalized engineering consideration was given to shipboard habitability design. In 1951, CINCLANTFLT concluded that the addition of equipment and personnel to ships which were not designed to accommodate them was adversely affecting their military effectiveness. As a result, standards were established to obtain and maintain adequate habitability. Although the standards provided a degree of protection against degradations from other systems, they were not responsive to specific ship requirements. In 1968, NAVSEC initiated its current Habitability Improvement Program. Although the program concentrated on upgrading existing ships, improved habitability was achieved in new designs through the application of the standards, PMI's, and Fleet input. In 1975, a more responsive approach was developed and applied to the CV concept design. Certain steps in the approach were not carried out, preventing the approach from fully achieving its goals. For example, design participants generated requirements in terms of space, furniture and equipment versus operational objectives. The proposed process is directed at correcting these deficiencies and obtaining habitability designs responsive to specific ship requirements. Improved means for maintaining (controlling) habitability after design are needed, but were not addressed in this paper.

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